NUMERICAL STUDY ON RETROFITTING OF BEAM COLUMN JOINT STRENGTHENED WITH CFRP

N.NAVEEENA[1], M.RANJITHAM[2]

[1]PG Student, Civil Engineering, Dr.Mahalingam College Of Engineering & Technology, Pollachi,Tamilnadu,India.

[2]Assistant professor, Civil Engineering, Dr.Mahalingam College Of Engineering & Technology, Pollachi,Tamilnadu,India.

Abstarct - In reinforced concrete structures, beam column joint are considered as most damageable structural element subjected to lateral loads. In the paper a finite element model for exterior beam column joints is presented to stimulate the seismic behaviour of RC existing structure with design criteria. The Retrofitting of existing structure is one of the major challenges in the modern civil engineering structures. This paper presents the jacketing method for strengthening or retrofitting of exterior beam column joint, to enhance their strength and stiffness. An analytical model is proposed to predict the shear capacity strengthened with carbon fibre reinforced polymer (CFRP).The axial load were applied at the column top of the surface and held constant during the test. The free end of the beam subjected to cyclic loading Two specimen one is unstrengthened and another is strengthened specimen with CFRP were modelled and analysed. An effective re-habitation strategy is in order to increase the ductility of the beam column joint and transfer the failure mode to beam or delay the shear failure mode. The specimens are then loaded with step by step load increment procedure to stimulate the cyclic loading in testing. The stress and deformation results were evaluated and compared their results with strengthened and unstrengthened specimen. The numerical result shows that the beam column joint strengthened with CFRP can increase their structural stiffness, strength and energy dissipation capacity.

Keywords:*Retroffiting,Exterior beam column joint, Carbon fibre reinforced polymer, Cyclic loading,ANSYS.*

1. INTRODUCTION

1.1 GENERAL

In reinforced concrete frames, T connections (exterior beam column joint) have recognised as a weaker components when subjected to cyclic lateral loads. Several damages of connection in general and of a T connection in a particular section may cause deterioration of whole performance of frame. Many RC frames are originally designed to carry only gravity loads. They lack the ductility and strength to present a global failure mechanism caused by cyclic loading conditions. These structures typically have a non-ductile reinforcement at the beam column joint areas in terms of inadequate transverse reinforcement and strong column weak beam design. Strengthening of existing reinforced concrete structures is now a major part of construction activity all over the world. The RCC structures constructed across the world are often found to exhibit distress and suffer damage, even before service life is over due to several causes and earthquakes, corrosion, overloading, change of code provisions, improper design, faulty construction explosions and fire. For all framed structures the most important is beam column joint, and the structural design of joint is neglected during the design stage, attention is only resisted to provision of sufficient anchorage for the beam. Unsafe design and detailing within the joint is dangerous for the entire structure, even though the structural members themselves may confirm to the design requirements. It is well known that joint region in reinforced concrete framed structures are recognized as very critical as it transfer the forces and bending moments between the beams and columns. In most cases during extreme loading, the beam column joints, if not designed properly are the most vulnerable component. With the advent of revised design and detailing codes and detailing codes and increase in the earthquake vulnerability level of many regions, the existing structures needs retrofitting and strengthening.

1.2 TYPES OF BEAM COLUMN JOINTS

Beam column joints are generally classified with respect to geometrical Configuration and identified as interior, exterior and corner joints. The fundamental differences in mechanism the shear requirements, two types of joints such as interior joint and exterior joint are considered. With respect to the plane of loading, an interior beam-column joint consists of two beam on either side 5 of the column and an exterior beam-column joint has a beam terminating on one face of the column.

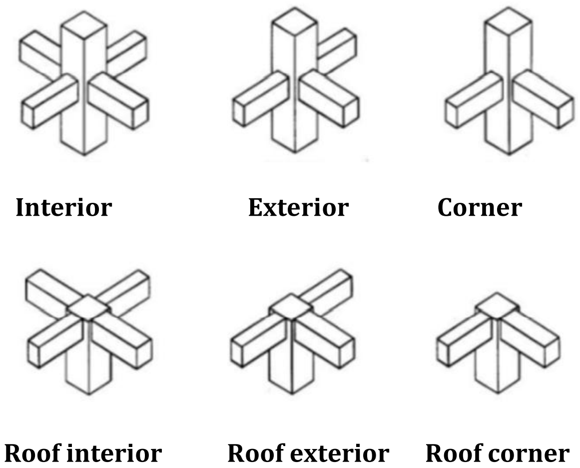

Figure 1.1 *Diferent type of joints*

1.3 CARBON FIBRE REINFORCED POLYMER

Carbon fiber-reinforced polymer, carbon fiber-reinforced plastic or carbon fiber-reinforced thermoplastic (CFRP, CRP, CFRTP) or often simply carbon fiber, or even carbon), is an extremely strong and light fiber reinforced polymer which contain carbon fiber.

The reinforcement will give the CFRP its strength and rigidity; measured by stress and elastic modulus respectively. Unlike isotropic materials like steel and aluminium, CFRP has directional strength properties. The properties of CFRP depends on the layouts of the carbon fiber and the proposition of the carbon fibers relative to the polymer

Despite its high initial strength to weight ratio, a degree limitation of CFRP is its lack of a definable endurance limit. This means theoretically that stress cycle failure cannot be ruled out. While steel and many other structural metals and alloys do have estimate fatigue endurance limits, the complex failure modes of composites mean that the fatigue failure properties of CFRP for critical cyclic load applications, engineers may need to design in considerable strength safety margins to provide suitable component reliability over its life service.

ADVANTAGE FOR CFRP

- High tensile strength
- High strength to weight ratio
- Low weight to volume ratio
- Excellent fatigue behavior
- Quick application

CFRP composite was able to strengthen the shear capacity as well as the ductility of beam column joint.

Table (1) Material properties of CFRP

FRP composite	Elastic modulus (Mpa)	Major poison's ratio	Tensile strength (Mpa)	Shear modulus (Mpa)	Thickness of laminate mm
CFRP	$E_x = 2.3e5$	$v_{xy} = 0.22$	3.5e3	$G_{xy} = 1.179$	1
	$E_y = 1.79e5$	$v_{xz} = 0.22$		$G_{xz} = 1.179$	
	$E_y = 1.79e4$	$v_{yz} = 0.30$		$G_{yz} = 6.88e$	

2. EPOXY RESIN

- Epoxy resins are relatively low molecular weight pre-polymers capable of being processed under a variety of conditions.
- They exhibit low shrinkage during cure.
- The cured resins have high chemical, corrosion resistance, good mechanical and thermal properties, outstanding adhesion to a variety of substrates, and good electrical properties.
- CFRP improves the compressive strength and reduces the crack propagation

3. SHEAR FAILURE OF EXTERIOR BEAM-COLUMN JOINT

A typical detail of exterior beam-column joint and acting horizontal forces. As acting load becomes lager, the compressive stress generates at inside of bent portion of beam bars with the deterioration of bond performance in straight portion. Joint shear is considered to be transferred by both of compressive force in concrete strut formed between bent portion and beam compressive zone and tensile force generating in joint transverse reinforcement after concrete cracking. Joint shear strength is decided by compressive fracture of concrete strut or yielding of joint reinforcement. AIJ (Architectural Institute of Japan) design guideline (AIJ 1999) defines the equation for joint shear strength as Eqn. 1.1 on the condition of minimum joint reinforcement volume of 0.3%, where joint reinforcement is not considered. This design equation intent to give the shear strength at story displacement of beam yielding and it tends to show the safety estimation.

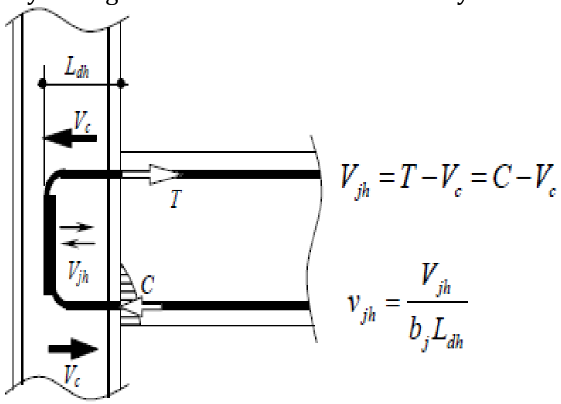

Figure 1.2 Force acting at exterior beam-column joint

$V_{iu}\, F_j\, b_j\, D_J$

Where,

k- Coefficient for joint configuration k= 0.7 for exterior joint

Ø- Coefficient of existence of transverse beams,

Ø-1.0(both side0.85 (others)

F_j - fundamental joint shear strength,

F_j-0.8 $_B{}^{0.7}$(N/mm^2)

$b_{j\,=}$ joint effective width

D_j = column depth (interior joint) or development length L_{dh} of hooked bar (exterior joint)

4. OBJECTIVE

The main objective of this thesis is to study about the strength and serviceability of the CFRP retrofitted beam column joint. Also

- To develop an effective rehabilitation in order to strengthen the beam column joints to avoid or delay their shear failure.
- To increase the shear capacity of beam column joint using carbon fiber reinforced plastic materials.
- To improve the seismic performance of damaged building in terms of lateral strength and serviceability.
- To determine the load deflection behavior of damaged beam column joint strengthened with CFRP when it is subjected to cyclic loading
- To compare the behavior of unstrengthened and strengthened specimen.

5. STRUCTURE DIMENSION

Size of the column 150 x 200 mm

Size of the beam 150 x 200 mm

Height of column 800 mm

Length of the beam 600 mm

6. REINFORCEMENT DETAILS

COLUMN: 4 no's of 12 mm diameter longitudinal reinforcement. 8mm diameter bars @ 150mm C/C distance.

BEAM : 4 no's of 12 mm diameter bars 8mm diameter bars @ 100 mm C/C distance

7.1INTRODUCTION

The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. ANSYS is a general purpose finite element (FE) model in ANSYS. Here a linear analysis is considered throughout is considered through the study by assuming that there is a perfect bonding between reinforcement and steel.

7.2 FINITE ELEMENT MODELLING

7.2.1 Concrete modelling

Behaviour of the concrete

Concrete exhibits a large number of micro cracks, especially, at the interface between closer aggregate and mortar, even before subjected to any load. The presence of these micro cracks has a great effect on the mechanical behaviour of concrete, since their propagation during loading contributes to non-linear behaviour at low stress levels and causes volume expansive near failure. Many of these micro cracks are caused by segregation, shrinkage or thermal expansive of the mortar. Some micro cracks may develop during loading because of the difference in stiffness between aggregate and mortar. Some micro cracks may develop during because of the difference in stiffness between aggregate and mortar. Since the aggregate-mortar interface has a significantly lower tensile strength than mortar, it constitutes the weakest in the composite system. This is the primary reason for the tensile strength of concrete. The response of a structure under load depends to a large extent on the stress strain relation of the constituent materials and the magnitude of stress. Since concrete is mostly in compression, the stress-strain relation in compression is of primary interest.

7.2.2 Element properties

SOLID65 is used for 3-D modelling of solids with or without reinforcing bars (rebar). The solid is capable of cracking in tension and crushing in compression. In concrete applications, for example, the solid capability of the element may be used to model the concrete while the rebar capability is available for modelling reinforcing behaviour. Other cases for which the element is also applicable would be reinforced composites (such as fibre glass), and geological material 9such as rock). The element is defined by eight nodes having three degree of freedom at each node: translations in the nodal x, y, z directions.

7.2.3 Steel reinforcement

To model concrete reinforcing, discrete modelling is used by assuming that bond between steel and concrete is 100 percent. Beam column has six degree of freedom at each node. These include translations in the x, y, z directions and rotations about the x, y, z directions. This element is well-suited for linear, large rotation, and large strain nonlinear applications.

7.2.4 Laminates

To model laminated composites SHELL 91 is used. It may be used for layered applications of a structural shell model or for modelling thick sandwich structures. Up to 100 different layers are permitted for applications with the sandwich option turned off. When building a model using an element with fewer than three layers SHELL91 is more efficient than SHELL 99.

7.3 MATERIAL PROPERTIES

Linear analysis considered for modelling RC beam column, table summarizes the material linear properties and elements used in the modelling

Table (2) Different Material Property

Materials	Density (kg/m3)	Elastic modulus (Mpa)	Poison's ratio	Fc28 (Mpa)	Fy (Mpa)	Element used
Concrete	2200	22360	0.15	20	-	SOLID 65
Reinforcing steel	7850	2e5	0.3	-	415	Beam 188

8. EXTERIOR BEAM COLUMN JOINT WITHOUT CFRP WRAPPING

The structural geomentry of exterior beam column joint has been modelled for the mentioned dimension and analysed using ANSYS. The exterior beam column joint has been analysed without CFRP wrapping. The bottom of the column is constrained in all degree of freedom. The cyclic load of up to 30KN is applied on the beam

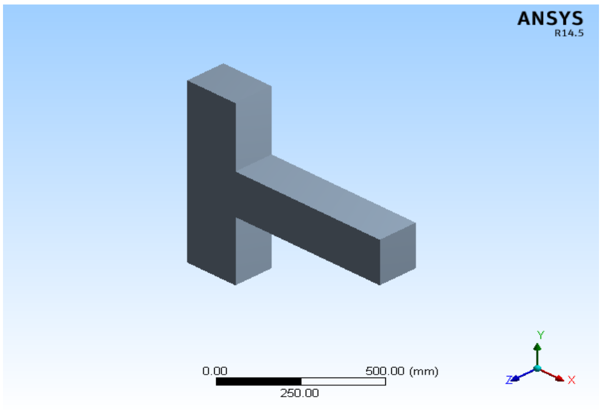

Figure 8.1 *The exterior beam column joint model*

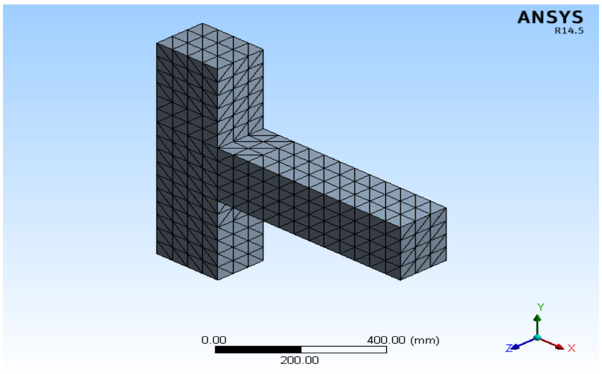

Figure 8.2 *Mesh model for exterior beam column joint without wrapping*

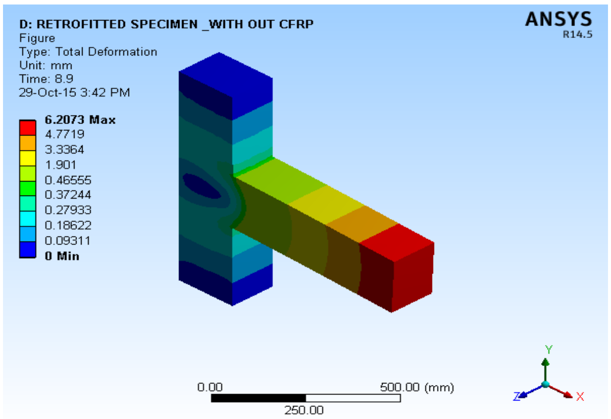

Figure 8.3 *Deflection for concrete exterior beam column joint without cfrp wrapping*

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 03 Issue: 01 | Jan-2016 www.irjet.net p-ISSN: 2395-0072

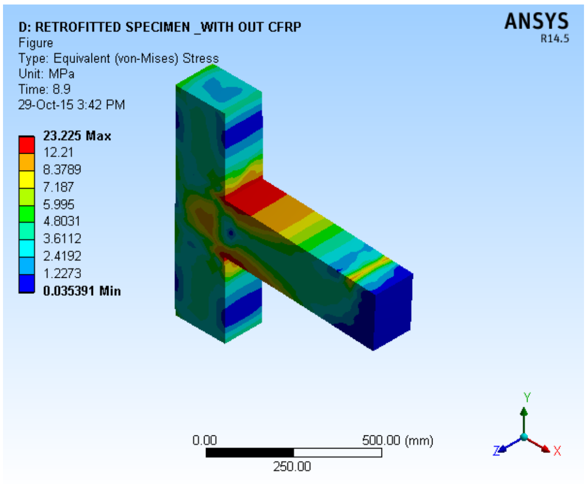

Figure 8.4 *Equivalents stresses for concrete the beam column joint without cfrp wrapping*

9. EXTERIOR BEAM COLUMN JOINT WITH CFRP WRAPPING

The structural geometry of exterior beam column joint has been modelled for the mentioned dimension and analysed using ANSYS. The exterior beam column joint has been analysed without CFRP wrapping. The bottom of the column is constrained in all degree of freedom. The cyclic load of up to 60KN is applied on the beam. The thickness of wrapping of CFRP is 1.5mm. Poison ratio is 0.22.young modulus 230000Mpa. And it is wrapped on300mm length on all sides.

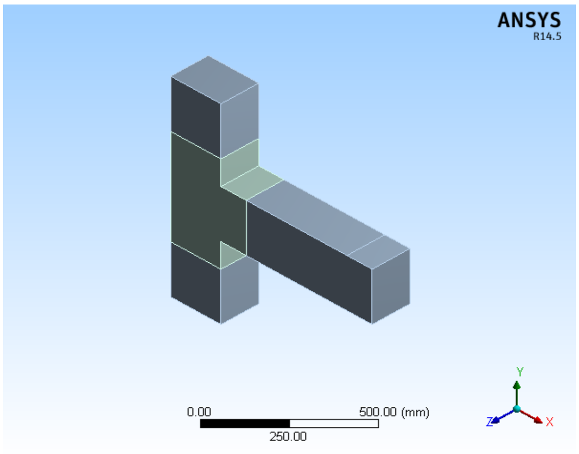

Figure 9.1 *The exterior beam column joint model with cfrp*

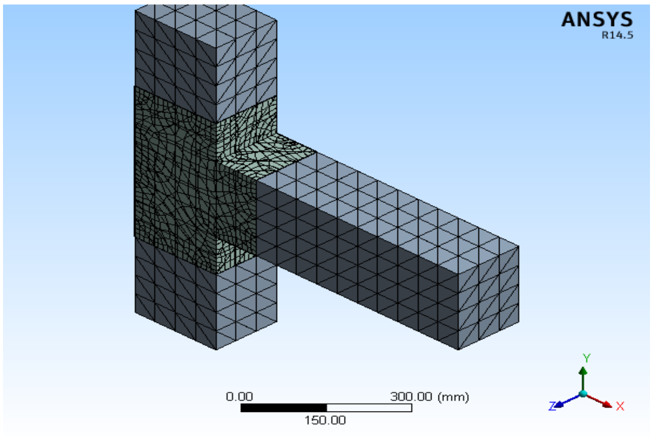

Figure 9.2 *Mesh model for exterior beam column joint with cfrp wrapping*

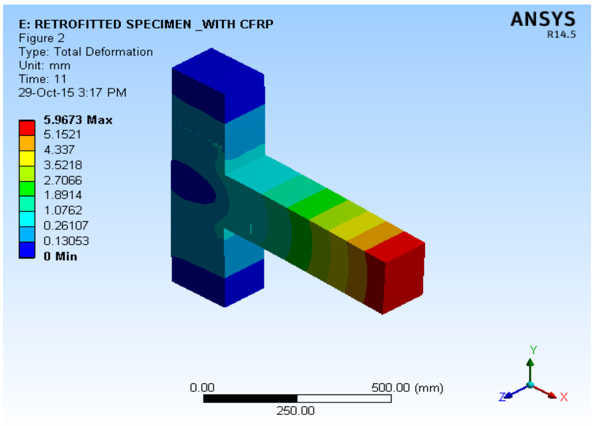

Figure 9.3 *Deflection for exterior beam column joint with cfrp wrapping*

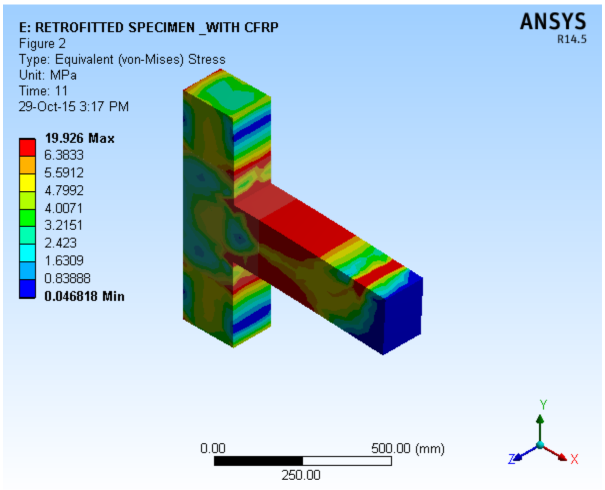

Figure 9.4 *Equivalent stress for concrete the beam column joint with cfrp wrapping*

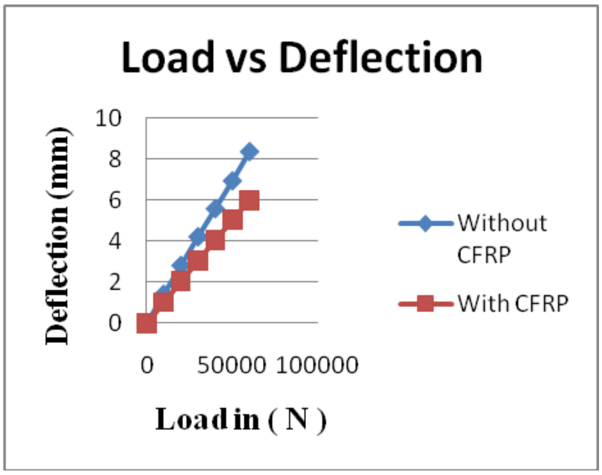

Chart 1 *Load vs deflection curve result and discussion*

In this chapter the numerical results of both with CFRP wrapping and without CFRP wrapping are interpreted. Their behaviour throughout the analysis is studied from the recorded data obtained from the deflection behaviour and load carrying capacity using ANSYS. The strengthened and unstrengthened beam column joints are tested for their ultimate strength.

1. The load carrying capacity of the retrofitted specimen is 30% more than the unstrengthened specimen.
2. The load deformation characteristic also improves to the large extent in case of retrofitted specimen over unstrengthened specimen.
3. The ductility of the retrofitted specimen will be more when compared with the normal specimen
4. CFRP retrofitting specimen of the beam column joint shifted the failure of the joint from column portion to the beam portion of joint which will prevent progressive collapse.

10.CONCLUSION

The following observations and conclusions can be drawn based on the analytical results of the study.

1. Comparing the numerical investigation we can confirm that the deflection in the strengthened specimen is comparatively lesser than that of the unstrengthened specimen.
2. It is observed that the stress in the specimen is better in the retrofitted with CFRP specimen when compared with the normal specimen without CFRP wrapping.
3. From the overall study, it can be concluded that the strengthening with CFRP structure will increase the serviceability of the structure.

REFERENCES

1. Kien Le-Trung , Kihak Lee , Jaehong Lee , Do Hyung Lee , Sungwoo Wooc *"Experimental study of RC beam–column joints strengthened using CFRP composites"*vol. 76-85,2010
2. Guo-Lin Wang, Jian-Guo Dai , J.G. Teng. *,"Shear strength model for RC beam–column joints under seismic loading."*,vol. 48-60,2010
3. W.T. Lee a, Y.J. Chiou a,b, M.H. Shih c*" Reinforced concrete beam–column joint strengthened with carbon fiber reinforced polymer"*,2009
4. Mohamed H. Mahmoud, Hamdy M. Afefy , Nesreen M. Kassem, Tarek M. Fawzy , *"Strengthening of defected beam–column joints using CFRP"*.vol. 65-67,2014
5. Hiroshi OKANO1, Tomohisa MUKAI2, Setsurou NOMURA3 and Takanori SUGANUMA,*"Experimental study on the failure behaviour of RC exterior beam-column joint at top floor"*.vol. 350-360
6. R.L. Vollum and juan sagaseta *"Shear strengthening of reinforced concrete beams with CFRP"* article in Arabian journal for science and engineering vol·130-139,2010
7. Varinder Singh , Prem Pal Bansal , Maneek Kumar , S.K. Kaushik (2014) *"Experimental studies on strength and ductility of CFRP jacketed reinforced concrete beam-column joints"*vol.194-201,2014.
8. Muhammad N.S. Hadi , Tung Minh Tran *"Retrofitting nonsensically detailed exterior beam–column joints using concrete covers together with CFRP jacket"*.vol.161-173,2014
9. G. Metelli F. Messali , C. Beschi , P. Riva *"A model for beam–column corner joints of existing RC frame subjected to cyclic loading"*vol.79-92,2015
10. Minakshi Vaghani , Dr. S.A. Vasanwala , Dr. A.K. Desai *"Performance of RC Beam Column Connections Subjected to Cyclic Loading."* Vol 12,2015
11. Kazuki TAJIMA, Takamichi MISHIMA, Nobuaki SHIRAI ,*"3-d finite element cyclic analysis of RC beam/column joint using special bond model"*vol. 345-400, 2003
12. Amlan K. SENGUPTA, CHEMURU Srinivasulu Reddy , Badari Narayanan V T and Asokan A,*"Seismic analysis and retrofit of existing multi-storeyed buildings in India – an overview with a case study."*2004
13. Ma'en S. Abdel-Jaber1), Anis S. Shatanawi2) and Mu'tasim S. Abdel-Jaber "*Guidelines for Shear Strengthening of Beams Using Carbon Fibre-Reinforced Polymer (FRP) Plates*" vol.1 no 4,2007
14. R. Eligehausen, G. Genesio & J. Ozbolt,"3D analysis of seismic response of RC beam-column

exterior joints before and after retrofit"vol. 24,2004

15 .Osamu JOH And Yasuaki GOTO "*Beam-column joint behaviour after beam yielding in r/c ductile frames"*,2004

16 A. Bukhari, R. L. Vollum†, S. Ahmad* and J. Sagaseta "*Shear strengthening of reinforced concrete with CFRP"*vol65-67,2010

17 IS-456-2000 Indian standard ductile detailing of reinforced concrete, code of practice. BIS, New Delhi, India.

18 Kadhim "*Effect of CFRP sheet length on the behaviour of HSC continuous Beam"*,vol.00,2012

19 Mukheerjee A.Joshi M."*FRPC reinforced concrete beam column joints under cyclic exiction*"vol.185-99,2005